J. F. Campbell Esq. F.G.S.
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ICE & ICE-WORK IN NEWFOUNDLAND.

[*Extracted from the* GEOLOGICAL MAGAZINE, July, August, September, 1876.]
TRÜBNER & Co., 57 and 59, Ludgate Hill, London.

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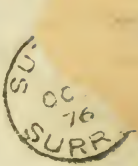


Sent by
Mrs Arnott
Milne Lodge
Silton Surrey

ICE AND ICE-WORK

IN NEWFOUNDLAND.

BY

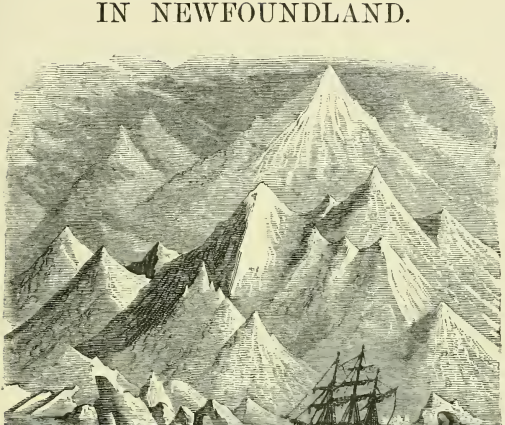
JOHN MILNE, F.G.S.,

PROFESSOR OF GEOLOGY IN THE IMPERIAL [redacted] OF TOKEI, JAPAN.

[Extracted from the GEOLOGICAL MAGAZINE, Decade II. Vol. III., Nos. 7, 8, 9, July, August, and September, 1876.]

ICE AND ICE-WORK

IN NEWFOUNDLAND.



"And now there came both mist and snow,
And it grew wondrous cold;
And ice, mast high, came floating by,
As green as emerald.

And through the drift the snowy cliffs
Did send a dismal sheen;
Nor shape of men, nor beasts we ken—
The ice was all between.

The ice was here, the ice was there,
The ice was all around;
It cracked and growled and roared and howled,
Like noises in a swound."—COLERIDGE'S *Ancient Mariner*.

The rough MS. of this Article was placed in the Editor's hands by his friend Mr. Milne early in 1875, but, owing to pre-occupation on the part of Editor and Author, was never put in type until this month, June, 1876. The author departed in August last for Japan, and has therefore been prevented from again seeing or revising his notes. The Editor trusts that this apology will be accepted by the reader should he find that the author has omitted to notice any papers on ice as a geological agent, which may have been published since that date.—EDIT. GEOL. MAG.

We often see a certain cause at work, and then its effect;—and the effect may be and is, doubtless, in many instances, peculiar to the cause. In Switzerland glaciers are known to have rounded and converted into "hummock"-shaped forms the rocks over which they have passed; whilst the rocks which were imprisoned in the ice, and used as tools to scour the rocky bed over which they moved, have in their turn also received a definite impression.

Hummocky tracts of land like those in Switzerland are to be seen in Scotland, Newfoundland, and other countries. Mounds of debris, filled with scratched stones like those produced by a modern glacier, are to be found in many places. These and other appearances, which are peculiar to ice-action, are ascribed to it as their originators; for, whether they be of Permian or Pleistocene age, their origin would seem to be identical.

By studying the effects of modern volcanic outbursts, similar paroxysms can be shown to have occurred in bygone ages,—and it is only by having a knowledge of the present, that any true knowledge of the past can be obtained.

The action of ice upon the surface of the earth has been spoken of in all our Manuals and Text-books of Geology. De la Beche, Lyell, Ramsay, Jukes, Geikie, and others, all discuss it in its various forms.

The fact that existing glaciers had once a wide extension was not however observed earlier than 1821, when M. Venetz advanced the opinion with regard to those of the Alps. In 1836 these ideas were strengthened by the observations of M. Charpentier; but it was not until the distinguished naturalist Agassiz—fresh from the same Alpine school, where so many geological truths have been demonstrated—visited Scotland in 1840, that the curious rock-markings in that country were successfully shown to be identical with those produced by the glaciers of Switzerland.

Glaciers have been regarded from many points of view, and have been studied both mathematically and physically. Their effects have been noted, and they are now universally admitted to have been great tools in the modelling if not in the actual formation of the surface configuration of the earth. They were first suggested and shown to be a means of solving the puzzles of drift, rounded rocks, strange scratchings, and boulders, and ever since take the precedence of all other ice.

Their offspring, the Icebergs, have also been studied, and their work has been duly chronicled. The manner in which they bear rocks to warmer seas, and strew them broad-cast over the bed of the ocean, and even the way in which they may have aided in modelling a rising area, has long been dwelt on; but, being less important tools in Nature's workshop than their parents the Glaciers, deservedly without such emphasis. There is, however, another form of ice, which, from its unassuming appearance, although touched on by a few, has apparently taken too low a place in the rôle of actors with which it plays. This is the Coast-ice.

My first sight of large masses of floating ice was on my arrival at St. John's, Newfoundland, in the spring of 1872. On the morning of the 16th of May, we found ourselves wrapped in a fog, through which a high bold coast was dimly visible. At length it lifted, and we saw ourselves in a cliff-bound bay, at the head of which a narrow entrance showed us a harbour filled with ice and ships. Near us floated two great icebergs, whilst the sea around was covered with smaller lumps jostling against each other as they rose and sank upon the swell. This Arctic scene is depicted as occurring at the same place, but on a grander scale, in the frontispiece of "Frost and Fire," by J. F. Campbell, F.G.S.

This mass, consisting of floe-ice surrounding icebergs, was travelling southwards under the influence of the cold Arctic current, which, coming from the northern regions, after coasting along by Labrador, sweeps onward past Newfoundland, to sink beneath the warmer waters of the Gulf-stream in more southern latitudes.

On the coast of Newfoundland Icebergs generally make their appearance about the 1st of January. Their approach is heralded by a number of smaller pieces. When we reflect upon the origin of these bergs, it would appear that the greater number of them ought to be disengaged from their parent mass, the glacier, in summer-time. The semifluid mass, of which the glacier is made up, creeping slowly, like a frozen river, down the valley by the aid of heat, gravity, etc., has in summer-time its pace augmented by the increment it receives at this season of the year.[1] It then pushes itself rapidly forward into the ocean, and there by the buoyancy of the water the projecting ice-mass is detached and floated off. Why, therefore, is it that the bergs are not seen off the Coast of Newfoundland at the close of summer, or at the latest in the "fall" of the year? The answer to this may be obtained from the inference of Sir Edward Belcher, and other Arctic navigators, who tell us that in very high latitudes the ice appears to be in motion much earlier than it is farther to the South. On the 20th of May the western side of Smith's Sound has been found to be quite open for navigators in a boat, whilst Barrow Strait is not navigable till late in August. The consequence of this would appear to be that whatever ice may be set free far north early in the year is detained in more southern latitudes until the fall. Another cause also operating in keeping the ice off the coast until the spring of the year may be the wind. Although icebergs, with regard to their motion, and the direction of the wind, often present curious anomalies, yet this must to a slight degree be influential on their wanderings. In the "fall" of the year the prevalent winds on the North American side of the Atlantic are generally speaking from the west, which tend to keep all bergs out at sea, and thus,

[1] Sir James Ross, from his observations in the Antarctic Seas, infers from the greater difference between the temperatures of the sea and air in winter-time than in summer, that it is at the former season of the year that the greater number of bergs are detached.

to observers on the land, they would be lost sight of; but in the spring of the year the winds are more or less northerly, which would only aid the current in bringing the ice along shore. The most apparent suggestion for the detention of the ice before reaching the shores of Labrador and Newfoundland is of course the distance it has to travel; but considering the steady rate at which this is carried on in the stream which bears them, the effects of wind, and the delay in the breaking up of the Southern Arctic barrier must have the precedence.

Theoretical considerations on the Flotation of Icebergs.—The icebergs I had the opportunity of seeing daily for several weeks whilst in the neighbourhood of St. John's, although irregular in their outlines, were by no means of such varied forms as many that were seen afterwards. Several apparently very small pieces, projecting perhaps not more than a foot out of water, when approached showed themselves as considerable masses, their magnitude being hidden by their submergence. In the "offing" "islands of ice," as the bergs are here called, were to be seen moving southwards, whilst in the bay several of them were always to be seen aground. These latter, as they slowly rose and fell with the ever-varying swell caused by the wind and tide, were deranging and grinding away the beds on which they rested. The enormous power that one of these islands of ice must possess to do such work may faintly be conceived by approaching one of them in a boat, and then considering that, although there is a mountain above water, there is from seven to nine times its mass beneath the surface. The depth of water in which one of these ponderous masses of ice can ground may often be more limited than has generally been expressed. When the berg first leaves its parent the glacier, its sides may be more or less parallel to each other, and we may sometimes get a near approach to a prismatic form. In this case not only would there be about eight times the bulk of ice beneath the water as there is above, but also there will be about eight times the depth, and we might conceive, as Jukes and Geikie tell us in their "Geology" (p. 416), that if the mass rises "300 feet above the waves," we may imagine that it "has its bottom 2,400 feet below them." In the Arctic and Antarctic regions we may therefore understand the immense depths at which an iceberg can ground, and there disturb the strata. As bergs travel towards lower latitudes, as towards Newfoundland, what with the beating of the waves and the changing of temperature they of necessity lose a great deal of the regularity of character they may previously have possessed. The greatest loss appears to be upon the portion exposed to the atmosphere, but, perhaps, more noticeable "between wind and waters."

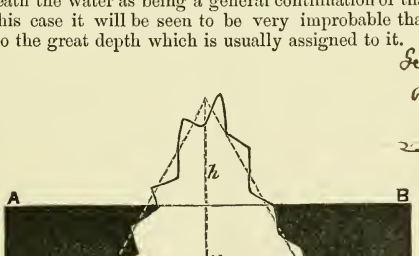
As this waste goes on, the berg must rise, and the ratio of the height of the exposed portion to the depth of that which is hidden grows greater. The result of this is that the exposed portion becomes less and less in diameter than that which is protected beneath the surface of the water, which at last may be looked upon as a kind of foot or pedestal.

That bergs, instead of descending in parallel sides beneath the surface of the water, rather extend outwards in the form of a broad base, depends on the assumption that the disintegration is carried on at a greater rate above water than below.

Apart from these theoretical considerations, it would seem from actual observations, that although icebergs have occasionally been seen in low latitudes to ground in deep water, as mentioned by De la Beche in his "Geological Observer," where one is recorded as being stranded in 720 feet of water on the Banks of Newfoundland, the bulk of them is only to be seen upon the shoals. In fact the grounding of icebergs is used by both the fishermen of Newfoundland and Labrador as a means of finding out shallows which may be used as fishing-grounds.

If a berg is seen to ground some distance out at sea, its bearings from the land are at once observed, and it is in this way that many of the banks have been discovered.

If, instead of taking such an extreme case as the one to which I have been referring, where the generally peaked appearance of a berg, as seen above water, might be imagined as standing on a wide-spread flat base beneath the water, we consider the portion of the berg beneath the water as being a general continuation of that above, even in this case it will be seen to be very improbable that the ice extends to the great depth which is usually assigned to it.



For example, in the accompanying figure let A B be the surface of water in which we see a piece of ice floating as indicated by the black line, the general direction of that beneath the water corresponding to that which is above. Approximating to such a figure, draw on the "give-and-take" system a many-sided pyramid, or in the limiting case a cone approximately equal in volume to that of the supposed berg. This is shown by the dotted line. We have given that the position of the cone beneath the surface of the water to that which is exposed are to each other in the ratio of 8 to 1.

Therefore the volume of the whole cone, which we will call V, is to that which is exposed, which we will call v, as 9 is to 1, *i.e.* $\frac{V}{v} = \frac{9}{1}$.

But also, as similar solids are to each other in volume as the cubes of their corresponding dimensions,

$$\frac{V}{v} = \frac{9}{1} = \frac{(h + H)^3}{h^3},$$

where h equals the height of the small cone of ice above water, and H equals the depth of ice below the surface,

$$\text{whence} \quad \frac{h + H}{h} = \sqrt[3]{9} = 2{\cdot}080$$

$$\therefore \quad H = h \times 1{\cdot}080$$

which is equivalent to saying that in a floating cone of ice the depth below the surface of the water is but very little greater than that which is exposed above. If the ratio of $\frac{V}{v}$ had been equal to $\frac{8}{1}$, then H would equal *h, or the depth below equal that which is exposed above.* That the cone would tend to float with the apex upwards rather than downwards, may be inferred from the fact that this latter position, where the base would be upwards, would raise the centre of gravity nearer to the surface of the water, and thus bring about a condition of equilibrium not so stable as if the apex had been upwards.

These considerations, it must be borne in mind, are purely theoretical, and are only used as a means of giving a clearer idea of some of the conditions under which ice may be found floating, and especially such ice as has suffered disintegration in its wanderings.

Aspect of Newfoundland.—It has been suggested that the so-called glacial effects which are universally seen in temperate, and even in tropical regions, may in many cases have been due to an ocean on which great icebergs floated. These, as they moved from point to point (like huge pepper-castors), strewed broadcast boulders and detrital matter, such as are now to be seen over an area like that of Russia and parts of North America. The effect of the force of impact of these tremendous masses has also been dwelt on, and the way in which they could grind, smooth down, or rub up the surface of a submerged area, has also often been referred to.

Should the area thus acted on be a rising one, on its emergence it may show definitely the characters that have been impressed upon it, and these perhaps may in some respects be analogous to those produced by land ice. In the explanation of the superficial aspects of a country from some such considerations as these, one man may take his stand upon a glacier, and another upon an iceberg. An iceberg theory has been advanced in the case of Newfoundland as an explanation of the physical features of the island (see Quart. Journ. Geol. Soc., 1874, vol. xxx. p. 722). From the numerous raised beaches containing *Mya arenaria* and other Atlantic species still living in the surrounding seas, Newfoundland appears to have risen in later geological times. The island itself, its principal bays, its mountains, its lakes and rivers, its lines of igneous protrusions, its ice-grooves and scratches, and the general strike of the rocks,

which, as was shown by Jukes, may in part account for the tendencies of the other features, have all been shown to trend from about 27° E. of North to 27° W. of South.

These curious coincidences were in part explained by supposing Newfoundland as a rising area submerged 3000 feet beneath its present level, and some denuding agent like the present Arctic current with its load of icebergs passing over it. This theory, I believe, is looked upon as being considerably strengthened by observations over a large part of North-east America. With regard to the Newfoundland portion of the Western Continent, I wish to show that it is not so clearly to be demonstrated.

After watching several icebergs grounding, it appears to me that they would tend to give anything but a parallelism in their abrading action.

An iceberg aground slowly lurches and rolls, and turns from side to side, as it is differently affected by the wind, the tide, or a current, evidently tearing up and grinding in several directions the strata on which it rests.

To conceive the method in which icebergs acted to form the "parallelism of features," as seen in Newfoundland, a picture must be drawn, which I am afraid will hardly be taken as the true one. As the island rises, the lines of valleys and of the hills have been formed, and along these troughs, and by the ridges, the icebergs pass. This initial direction may, amongst other causes, be due to the configuration of pre-existing land, to the general direction in which detrital matter is strewn by an ocean current. Whilst the land is still beneath the surface of the water, we must imagine these huge islands of ice tripping along from hill-top to hill-top, sometimes just grazing the sides of a submerged valley, and sometimes scouring the surface of a hill, like butterflies before a breeze which try to stop at every tempting flower.

That they may have scattered the boulders which are to be found in most parts covering Newfoundland does not appear to be so great an impossibility as that they were the originators of the parallelisms; but even these, from the observations made by myself and my companion, the late Mr. T. G. B. Lloyd, F.G.S., during the summer of 1874, it appears to me that they might be ascribed to another origin.

Ice-Marks in Newfoundland.—On the eastern coast of Newfoundland, from the extreme South to Kirpon on the North, a distance of 300 miles, boulders and other indications of ice-action are to be seen in most parts: reference to them has been made in the Quart. Journ. Geol. Soc., London, 1874, vol. xxx., p. 725. Near St. John's, ice-grooves and scratches are to be seen up to considerable heights, whilst drift with well-marked stones cover the country. The narrow neck of land that separates the Bays of Trinity and Placentia affords considerable evidence of ice-work. Standing on the water-parting which divides the streams into one of these bays from those entering the other, the contour of the country, which is typical of many other parts of Newfoundland, may easily be viewed. All around is a rough brown surface of berry-bearing bushes and stunted spruce,

dotted here and there, over which there are small soft green marshes. These latter generally form the border to many a quiet pool, the dark surface of which seems only to be made as a reflector for a passing cloud or some bare ice-marked hummock, a few of which rise here and there, forming undulations in the surrounding level. In such places as this the rivers of Newfoundland have their source. Looking down the valley towards one of the bays, your eye wanders over a flat-topped expanse of spruce and other underwood, through which a few scattered pine-trees sometimes lift their heads. To the right and left of this dark mass of stunted underwood there is a line of scarp-faced hills, which look as though they might once have been feeders of moraine to a glacier which, as it slowly pressed itself downwards, ground against their sides. Above the cliffs along the sky-line of the hills, a few large boulders are distinctly visible. On climbing to the top of these hills, you would see beneath your feet a chain of lakes and ponds dotted in amongst the trees. Each of these would have its fringing of green marsh, across which a dark line showing the trampled path of the wandering 'Cariboo' would be well marked. Connecting these lakes in their upper portions are a series of rapids and small waterfalls; whilst lower down, as we approach the tideway, there are often long 'reaches' of steady water. Further north, similar signs are visible,—in Bonavista Bay, in Green Bay, and in many others.

In Green Bay, or, as it is sometimes called, "the Bay of Notre Dame," on the highlands above Belt's Cove, the country, for many miles in extent, is thickly strewn with boulders.

The climb up to this boulder-land (which on the side next the sea forms steep cliffs) is a precipitous one; on reaching the top you are on a brown-looking country in the main undulating as if ice-worn. In the depressions there are either small ponds or marshes, which are bounded by bare hummocks. Sometimes a small cliff-like scarp looks down upon you from still higher ground. The boulders are strewn everywhere, but more particularly upon the highest ground, and often upon extreme points. Several boulders were so perched on two points that they formed an archway beneath, which could be seen at a distance of several miles. In another case one boulder was seen resting upon another. In form they were subangular. Fragments were taken from these, and also from boulders in several other districts, and, so far as my examination went, I found that, if not represented by the rock of the surrounding country, they had representatives further west, and this generally in the Laurentian granites. Mr. Alexander Murray, F.G.S., of the Geological Survey, has made the same observation. Now if these boulders had been deposited by Icebergs, this portion of Newfoundland must at the very least have been 1000 feet lower than it stands at present. During the time of its elevation, and especially at the time of its emergence, these boulders must have been subjected to a considerable amount of rough usage, and have received many rolls. If they were protected by a covering of drift, which, to secure them from the action of the sea, must have been many hundreds of feet in thickness, then the

surface-configuration of the country might be difficult to be accounted for. Rough treatment, such as boulders receive upon a beach, would hardly have relinquished them in their present subangular condition, nor would it have left them upon the highest ridges, or poised them upon a peak, or perched them one upon another. On the other hand, I think it would rather have tended to smoothen them down and deposit them in heaped confusion in the valleys, and they would probably, in that case, have been derived from the North-East rather than from the West, as they seem to indicate. Let alone the mechanical forces, which are constantly at work upon a beach, the ordinary processes of disintegration, the result of subaerial conditions, must have exercised considerable influence during the ages that have elapsed, whilst the land was rising to its present elevation, and this especially upon such soft rocks as serpentine, of which many of these erratics consist. Such boulders as these seem to point to another origin rather than to that of a sea full of icebergs.

Further to the north the same circumstances are here and there presented. Sailing up the long straight shore of White Bay, a line of hills, whose topmost heights are fringed with boulders, are seen trending away before you to the northward, until their escarpment which faces the Atlantic grows dim, and is lost to view in the distance. After the red cliffs of Conche (which are almost the only fragment of Devonian Shale in Newfoundland) have been passed, Kirpon, the most northern settlement in the island, is reached. Boulders are to be found here, and some of them of immense size.

Western Newfoundland.—After leaving Kirpon, we pass the northern end of the long range of granitic hills, running parallel with the western coast, forming the great backbone of the country, and which give to it, in some respects, a contour not unlike that of Arabia, the slope leading to the eastern coast being flat and long, whilst that to the west is short and steep.

On the eastern side, from what I have already stated, it will be seen that boulders often form a prominent feature in the landscape, but on the west they have hitherto been found to be wanting. Last year (1874), however, I found them at several places, especially in Louis Hills. They all seemed to point to the Laurentian backbone for their origin. Roches moutonnées are not so prominent upon the west as they are upon the east, but scratchings and groovings along the shore (which will be spoken of hereafter under the head of Coast-Ice) are common everywhere.[1]

Drift.—In addition to all these evidences of ice-work seen in the shape of boulders and scratched rock surfaces, we have here and there patched over the country large deposits of drift filled with regularly striated rock-fragments.

[1] Many of the effects of ice now seen in Nova Scotia are described by Dawson in his "Acadian Geology," p. 64, *et seq.*, as resembling those now produced by frost and floating ice. Blocks of stone are shown to have travelled from elevation to elevation, across valleys which may have been accomplished by ice-floes or bergs. Other blocks again are shown to have travelled from low plains to the summit of hills, which is explained on the supposition that the land at the time of their deposit being slowly subsiding, and the ice-fields of successive years raising them higher and higher.

In the neighbourhood of St. John's the drift-covering is noticeably full of such stones. Similar material covering the country may also be seen in many other parts of the Avalon peninsula, where we have good sections of an unstratified clayey base, containing both pebbles and boulders.

Further to the north Mr. Murray has observed these superficial deposits occurring on a much larger scale. In Little Bay, near Terra Nova Mine, he has noted deposits consisting of "probably fifty or sixty feet of stratified clay, gravel, and sand containing modern marine shells at the height of about 40 feet above high-water mark."

In Hall's Bay, up Indian Brook, he also noted stratified deposits of clay, "which is sometimes of a reddish and sometimes of a drab or bluish colour." Although these stratified deposits appear to show a divergence from what has hitherto been observed by Packard and others in the neighbouring mainland of Labrador, they show considerable relation and similarity to observations which have been made further up the valley of the St. Lawrence in Canada. It would seem that at no very remote period Newfoundland has been almost if not entirely subjected to the action of ice. To this fact the rounded hills, the basin-shaped hollows, the scored rocks, the erratic blocks and the immense coverings of drift, all bear testimony; but the mode in which all these phenomena have been brought about is a matter so speculative that I shall refrain from doing more than indicating a possible manner in which they may have occurred, rather than attempting to give any definite solution to such an obscure enigma.

Conclusions. — The general conclusions which might appear naturally to result from a consideration of observations made by myself during two summers travelling in the island, and also those made by other geologists, are as follows :—

If Newfoundland has been steadily rising during past ages, as it now appears to have done at no very remote geological period, it may have been beneath the surface of the ocean. During the period when it was undergoing elevation, no doubt a considerable amount of debris and boulders were dropped by icebergs over its surface when the Laurentian backbone, which would be the first land to emerge, reached the surface, it formed a barrier for the coast-ice which would carry its load of boulders and strew them with those of the bergs. This latter, as will hereafter be shown, might to some degree have been influential in giving a definite character to the rising area. After the final emergence the climate of Newfoundland might still have been a cold one, and the same highlands which gave birth to coast-ice, probably next gave birth to glaciers which scooped and hollowed out a great portion of the remaining marine drift, and left the island with its present contour. After the raising of the great North-East and South-East ranges, first coast-ice flowed East and West, and afterwards the glaciers followed in a similar direction, and thus perhaps the origin of the boulders, those which are so curiously perched being due rather to the latter than to the former. Thus it would seem that icebergs and coast-ice pre-

ceded glaciers, but to say what might have come before the former of these agents, would only be diving deeper into the depths of a sea of speculation. From the scantiness and want of detail in their observations, it is useless attempting definitely to correlate them with those conditions observed in the adjoining continent of America, where it has been shown "that the oldest glacial deposits have yielded evidence of inter-glacial mild conditions" similar to those of the British Isles and Europe (Great Ice-age, Jas. Geikie, p. 428).

Coast Ice of Newfoundland.—Icebergs have an advantage over coast-ice in their imposing appearance, which has perhaps been in part instrumental in raising them to the high position which they now occupy as workers of Geological changes. Many Manuals of Geology, and many diagrams drawn to illustrate the same science, have oft-times portrayed a well-known flat-topped berg, carrying a rock, in the Antarctic regions; but neither books nor lecture-diagrams, taken collectively, give any adequate idea of coast-ice as a similar agent. From what I have seen of coast-ice and of its effects, I feel persuaded that it is an agent of at least as great, if not of greater universality than either glaciers or icebergs, and taken as a whole perhaps also as an agent of equal power. Of the various forms of sea-ice known as "berg-ice," "floe-ice," "pack-ice," and the like, the portion I would more particularly draw attention to is that variety which forms a narrow belt along the shore, known in Greenland as the "Ice-Foot."

It would appear that in the formation of the "Ice-Foot," just as in the precipitation of rain, and in the production of other natural phenomena, we may have either one or many causes called into operation. Sometimes these may all be equally active, whilst at other times the rôle taken by one cause is more important than that taken by another, all being governed by circumstances. Geikie, in "The Great Ice Age," pp. 67 and 68, tells us that the Ice-Foot of Greenland "owes its origin to the action of the tides." "The first frost of the late summer covers the sea with a crust of ice, which, carried upwards along the face of the cliff by the tide, eventually becomes glued to the rocks." It thus "grows in thickness with every successive tide, until it may reach a height of 30 feet, and sometimes even more, presenting to the sea a bold wall of ice, against which the floes grind and crush."

In Newfoundland and the South Coast of Labrador, although the formation of the Ice-Foot is no doubt oftentimes very similar to this, there are yet other agents, besides that of the tide, which are equally active.

First we will imagine this formation taking place on a gently-sloping shore.

The Ice-Foot.—The blasts of December and January drive the spray high up upon the land, and there it freezes as a cake of ice; day after day and night after night this continues, and the crust grows thicker. A drift or fall of snow may help it in accumulating, until it is at last from two to three feet in thickness. Stones of all sizes, from pebbles to boulders, on which this coating may rest, are now firmly set in "an icy maw" of ice, and are ready at the first

movement to cut and grind a path for themselves. The first calm weather the sea freezes out from this to form an equivalent to the "bay-ice" of the Greenland whalers. This, however, is only a thin coating, which is either broken up or piled upon itself by the first rough water coming from the "outside," or is driven off by a land breeze. This generally goes on until some portion of the Northern pack, coming south, meets with an adverse wind and is driven ashore. When we reflect upon the immense mass contained in one of these moving fields of ice, we can hardly conceive the energy that is stored within it. Everything has to give way before it, and the coast-ice, with its set of gravers firmly bedded in its base, is pushed high and dry, sometimes as much as 100 yards, back from high-water mark.[1] It is in this way, by the coming in of the Northern Pack, the rise and fall of the tide, and other causes, that the land-ice is driven ashore, and many of the scratches and grooves so common round the coast of Newfoundland have been made. As a rule, these markings are remarkable for their definition. Some of the scratches are so parallel, so long, and so like each other, and even in their character from end to end, that at first sight their origin might be doubted. Markings like these may be well seen in the harbour of St. John's Island. The rock in which they are impressed is a Calciferous Limestone, sloping gently seaward. It looks as though it had been planed perfectly flat, and then a series of parallel lines several yards in length, from three to six inches apart, and from $\frac{1}{8}$ to $\frac{1}{4}$ of an inch in depth, had been evenly ruled across the prepared surface. Sometimes, instead of these lines crossing an even plane, similarly-marked smooth trough-like hollows have been formed. These increasing in size in places give quite an undulating character to the shore, as at the entrance to Terra Nova River and elsewhere.

Such a piling up of ice by the driving in of the pack, whether it be inland or ashore, is amongst the sealers termed "raftering." At a certain distance out from land, where the pack-ice can float, it breaks off from that which is cemented to the shore. This latter, no matter how it may have been formed, whether by spray or piled-up pack-ice, goes under the general name of "balacada." It has been suggested to me that this term, like many Newfoundland names, may have its origin from the Spanish, it being a corrupted form of "barricado," a name very suggestive of the appearance and conditions it is intended to describe. The edge of the "balacada" is termed the "drain," which may average a depth of about four fathoms, up and down, while through the agency of wind and tide a continual chafing action is going on.[2] If the pack-ice can float up and down along the foot of a cliff, or in deep water near rocks, the consequences are the formation of horizontal grooves

[1] In the selection of Arctic papers for the Arctic Expedition of 1875, published by the Royal and Royal Geographical Societies, p. 49, Robert Brown speaks of sheet-ice and boulders during storms being driven and packed to a height of 50 feet.

[2] The grating against vertical cliffs is referred to in De la Beche's "Geological Observer," p. 280, and at p. 282 on coast-ice generally.

and scratches, and these in cases are carried to such an extent that the cliff may be undercut. The "balacada," in a position of this sort, is formed by the spray, and projects out a foot or two from the face of the cliff; the drain, with its floating-ice, being beneath.

In addition to the work done in scratching and grooving by the coast-ice, it also does much in the transportation of material. When in deep water, chafing along the face of a cliff, by its own horizontal and vertical movements, together with its continued force of impact on a heaving swell, it must detach a considerable amount of material. This, together with that which may fall upon its edge from the rocks above (which appear to be universally greater at the breaking up of a frost than at any other season of the year), is carried by the coast-ice to a new home. The chief agent, however, in the transportation of material is the "balacada," barrier-ice or ice-foot, attached to the shore. At low water this freezes to the ground on a shelving shore, and is at once firmly attached to both boulders and stones. When the tide rises, this ice, with its cargo, floats, and may be carried away. The difference in level between neap- and spring-tides is another cause which greatly accelerates the transporting power of the "balacada." A land breeze assists in the dragging off of portions that are only partially aground. These, with other causes, are always, during the winter season, more or less in operation in removing materials from one point to another.[1]

This immense transportive power of the coast-ice often occasions severe losses to the fishing population of Newfoundland and Labrador. Various articles, to remove which would involve considerable difficulty, such as anchors and cables, having been left upon the beach, have been carried off by the ice;—it has come along, and after, so to say, glueing itself to everything upon the the shore, has floated off with all to which it was attached. At three harbours, Tilt Cave, Englee, and Goose Cove, I heard lamentations over losses of this description; and no doubt, upon inquiry, similar cases might be recorded of every fishing settlement both in Labrador and Newfoundland. The fishermen seem to have transferred the name "Anchor Ice," from its original idea of ice which anchors itself to the bottom, to ice of this description which endangers the equipment of their vessels. Without actually freezing beneath the surface of the water, as in some of the shallower parts of the Baltic where ground-ice is formed, a species of anchor-ice is formed by the freezing of the "balacada" so firmly to the ground at low water, that at the rising of the tide it remains beneath the surface of the water. The consequence of these transportive movements is that much material, both boulders and pebbles are carried out to sea, and then deposited in a manner similar to that which

[1] Speaking of the Greenland Ice-Foot, Geikie, in his "Great Ice Age," p. 68, says that "during summer vast piles of rock and rubbish crowd the surface of the ice-foot." "To such an extent does this rock-rubbish accumulate that the whole surface of the shelf is sometimes buried beneath it, and entirely hidden from view." "Along the part of the coast of Greenland where the ice-foot is shed at the end of every summer, the quantities of rock débris thus borne seawards must be something prodigious."

has so often been explained in the case of icebergs. Another consequence is that similar materials are carried from point to point along the coast, and on the disappearance of the ice are left as monuments of its former existence. In places boulders may be seen lining the shores in long lines, like tiers of barrels on a wharf, as at Change Island. Boulders of this sort are referred to, and a sketch of them is given, in Lyell's Principles of Geology, vol. i. p. 381. I have here spoken irrespective of the immense quantities of boulders that are annually brought down attached to the "ground-ice" of rivers.

Movements of Coast-Ice.—On the first calm day the ice out at sea along the edge of the pack commences to break up, and small lakes and pools are formed between the pans. This appears to be due to the tide. In a calm five square miles of ice will rapidly open out and spread over 20 miles, during which it is greatly smashed about and tumbled. Capt. A. Jackman, to whom I am indebted for many facts regarding the action and formation of coast-ice, informed me that on one occasion he knew of two vessels closely wedged in the ice, which were separated 20 miles apart in one night during a calm. A wind from seawards only jams it the tighter on the land, whilst one from the shore sends it off in a body until there is sufficient water between it and the land, where a sea can form, upon which the ice is speedily dispersed. In calm weather the pack travels with the current, but at other times it follows the direction of the wind. Icebergs, on the contrary, although affected by the wind, have a more definite direction in their line of travel dependent on currents. The consequence of this would appear to be that the line of distribution of material derived from pack-ice is not so definite in its direction as that of icebergs. In both cases the proportion of the mass exposed above water to that which is submerged is equal. The explanation therefore appears to lie mainly in the fact that the pack only rests on the upper surface of the water, which is affected by the wind, whereas the iceberg, descending to greater depths, will move in a steady current unaffected by any such surface disturbances. The ratio of the surface exposed above water to that beneath it in the pan of ice, to that in the berg, must oftentimes also be influential in the explanation of this phenomenon. Should a berg be entangled in a pack, and the tide be contrary to the wind, the berg may hold its own against both the wind and pack, and, so to speak, will force for itself a passage. Capt. A. Jackman has, whilst frozen in the pack, travelled at the rate of from two to three knots per hour past bergs, but whether these were aground or not was not definitely stated.

Conclusions regarding Coast-Ice.—As before remarked, it would appear that coast-ice might at least be considered as an agent in the production of Geological changes equal in power to either glaciers or icebergs.

By this it is not wished to imply that a mile of coast-ice is equivalent to a mile of glacier, but rather that coast-ice, taken as a whole, from the extent of its area, may be reasonably compared as

a modelling and disintegrating agent of our globe with either the glaciers or icebergs.[1]

Looking at the Northern Hemisphere only, and comparing all the deeply indented coast-lines, say that of North America and Greenland, every yard of which is more or less subject to the action of coast-ice, with the portions throwing off glaciers to form bergs, it will be seen that the coast-ice must in quantity be infinitely greater than the glaciers. All the vast ice-fields which break loose from the frozen regions of the North, and we read of them 300,000 square miles in extent, and seven feet in thickness, are, in their passage South, driven in upon the land, and help to grind the coast-line and transport its boulders. The Northern field-ice, when it arrives in the latitudes of Newfoundland, is often seen to be covered with boulders, gravel kelp, and other materials, showing it to have been at some time or other in contact with the coast. Ice of this description is well known to the sealers, who carefully avoid it, knowing that seals will not be found upon "dirty jam." From this, together with other information I collected, it would seem that, amongst the inhabitants of Newfoundland, the action of coast-ice as a transporting agent is universally recognized, whilst icebergs in the same latitudes are seldom seen with earthy materials upon them. Capt. A. Jackman, during about 30 years of ice-service on the coast of Newfoundland and Labrador, only once saw a mass of stone of any size upon a berg, whilst coast-ice, with its load of material, has continually been met with. That this should be the case appears on consideration to be evident; for at the outset, when the berg leaves its parent, the glacier, in these Northern regions, it has but little moraine matter to carry,[2] whilst afterwards the winds tending to drive it in upon the shore seem to affect it but little.[3] Now and then it may disturb the strata, and perhaps carry off a portion of the material forming some bank on which it has happened to ground, but to approach the land, as coast-ice does after leaving its birth-place, it is for ever debarred. Carried along by a deep-sea current, with but

[1] Although it may be said that glaciers are not alone confined to Arctic regions, but are also to be seen in the highlands of more temperate climates, it must not be forgotten the distance south that coast-ice is found along shores like those of Labrador, Newfoundland, and Siberia, where glaciers are unknown.

[2] "Owing to the inland valleys (of Greenland) being filled up and levelled to the tops of the hills, there is well-nigh a total absence of those long trains of débris that thunder down the steeps of the Alpine Mountains, and gather in heaps along the sides of the glaciers."—Geikie, "The Great Ice Age," p. 62. Dr. Rink, however, saw moraines above Upernivik.

[3] It might be argued that the bergs carry a burden of rocks and débris frozen to their bases; but in Geikie's "Great Ice Age," p. 61, we read:—"A few stones may occasionally remain frozen into the bottom of the detached iceberg, but it is evident that the greater portion of the sub-glacial deposit must remain at the bottom of the sea," and at p. 71 we read: "By far the larger number of Arctic icebergs therefore contain no extraneous matter, and melt away in mid-ocean without leaving behind them any record of their voyage." However it would be unfair not to quote from the observations of Robert Brown (Quart. Journ. Geol. Soc. 1870, p. 687), who states that on ascending an iceberg he "almost invariably found moraine which had sunk by the melting of the ice into hollows, deep out of sight of the voyager sailing past."

little care for wind or wave, it cleaves a course through ice and water to more southern regions.

The work done by a glacier is slow and steady. On its surface it carries all that may fall upon it, whilst at its base it annually smoothens for itself deeper and deeper the rocky bed on which it rests.

When floating-ice is pushed ashore, we have a somewhat similar action; but in addition to this steady pressure, coast-ice has another mode of acting which is wanting in the glacier, viz. that of impact. A faint conception of what this is may be derived from the accounts we read of Arctic travel. "The growling and roaring," "the crash of meeting floes and fields of ice," "the broad fields of ice several hundreds of miles in area broken up into countless floes," "the hummocks and hills that are piled up under the tremendous pressure," have all been spoken of.

Scoresby gives a calculation of the blow which must be produced by one of these immense fields of ice which he mentions, as being equal to that of 10,000,000,000 tons. Now all these tremendous blows delivered by ice-islands floating down upon each other must be given in a similar manner to a rocky coast.

After once seeing the broken masses of the icy "pavement" of these Northern regions scouring along by cliffs and islands, jostling and cannoning with all it meets as it rises and falls on the heaving swell, one cannot help being impressed with the immense amount of work that it is capable of performing.

Possibility of a sequence in Ice-Action.—It has now been shown how coast-ice may, to a certain extent, give a character to a coast-line; how it may, by impact, remove all asperities, and how, by a steady pressure, it may groove and scratch, and even produce a surface not unlike the *roches moutonnées* of the glaciers. We will now consider whether those markings may be reasonably expected to remain as permanencies.

In Newfoundland, which appears to be a rising area, there is every reason to suspect that many of the markings seen round the coast, which have hitherto been attributed either to glaciers or icebergs, have been impressed by coast-ice. Whatever the iceberg may have done when the now dry surface was beneath the sea, on emergence must in all probability have been obliterated, and the surface remodelled by the action of the coast-ice. A striking instance of this modelling of what is probably a rising area is seen at Funk Island. This island lies almost 30 miles out in the Atlantic to the East of Newfoundland. It is about half a mile in length, very low and flat, and is situated right in the stream of the Arctic ice. The northern end of the island, which has every year to face this tremendous pressure of vast fields of ice, is visibly worn down and covered with erratic boulders; whilst the opposite extremity is a low but abrupt cliff. Had the flow of ice been from the south, the reverse would probably have been the case, and the low shelving wedge-like shore, which forms a slide for the ice to mount together with its load of boulders, would have been at the opposite extremity

of the island. On a rising area of this sort the impressions that have been made appear certainly to affect in a permanent manner even the contour of the island, and it does not seem unreasonable that scratches and boulders may in a rising area be similarly preserved. Should the rising area be in a climate like that of Greenland, the effects of coast-ice would in time be planed away by glaciers. If the area be a sinking one, the results may be reversed. The surface configuration of the land, whether produced by glaciers or other causes, will be remodelled by the coast-ice, and these in their turn, on reaching deeper water, will be affected by the icebergs.

Looking at the effects of ice-work in this way, we see that there is a possibility of a sequence in their action. In high latitudes, where the climate is a constant one, the sequence is definite. Should the climate, however, be variable, we might have a surface scoured by icebergs, and covered with debris not emerging from the sea, until a warmer temperature had dissipated the icy pavement that once floated, and in this way we might see the effects of icebergs in the modelling of a land-surface.

THE END.

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